SIMPLIFYING OPERATIONS WITH AN UPLINK/DOWNLINK INTEGRATION TOOLKIT

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ABSTRACT

The Operations Engineering 12113 (01 EL) at JPL, has developed a simple, generic toolkit to integrate the uplink/downlink processes, (often called *closing the loop*,), in JPL,'s Multimission Ground Data System. This toolkit provides capabilities for integrating telemetry verification points with predicted spacecraft commands and ground events in the Mission Sequence Of Events (SOE) (1 ocument. In the JPL ground data system, the uplink processing functions and the downl ink processing functions are separate subsystems that are not well integrated because of the nature of planetary missions wi th large one-way 1 ight time.s for spacecraft-to-ground communication. Our new closed-loop monitoring tool allows an analyst or mission controller to view and save uplink commands and ground events with their corresponding downlinked telemetry values regardless of the delay in downlink telemetry and without requiring mal-time intervention by the user.

An SOE document is a time-mdcmxl list of al] the planned ground and spacecraft events, including all commands, sequence loads, ground events, significant mission activities, spacecraft status, and resource allocations. The SOE document is generated by expansion and integration of space.cmft sequence files, ground station allocations, navigation file.s, and other ground event files. This SOE generation process has been automated within the OEL and includes a graphical, object-oriented SOE editor and real-time viewing tool running under X/Motif. The SOE toolkit was used as the framework for the integrated implementation.

The SOE is used by flight engineers to coordinate their operations tasks, serving as a predict data set in ground operations and mission control. The closed-loc)p S01 toolkit allows simple, automated integration of predicted uplink events with correlated telemetry points in a single SOE document for on-screen viewing and archiving. It automatically interfaces with existing real-time or non real-time sources of information, to display actual values from the telemetry data Stream.

This toolkit was designed to greatly simplify the user's ability to access and view telemetry data, and also provide, a means to view this data in the context of the commands and ground events that are used to interpret it. A closed-loop system can prove especially useful in small missions with limited resources requiring automated monitoring tools. This paper will discuss the toolkit implementation, including design trade.-offs and future plans for enhancing the automated capabilities.

INTRODUCTION

The Operations Engineering 1 ab (01;].) at NASA's Jet Propulsion Laboratory has developed a simple, generic toolkit that

integrates uplink events with downlink telemetry information, (often called *closing the loop*,). This toolkit provides capabilities for integrating telemetry verification points and ground monitoring information with planned spacecraft commands and ground events in the Mission Sequence Of Events (SOE) schedule. in the existing SOE for planetary missions, each spacecraft command item has a descriptive text field that contains a list of related engineering telemetry parameters. These parameters are monitored by mission controllers using a data monitor tool that processes and displays the downlink telemetry stream. However, the relevant downlink telemetry for command verification may not arrive for hours or even days after the commands have been sent because of the large one-way light times and limited contact periods of some planetary missions. The closed-loop system will integrate these tasks by interfacing the SOE with the mal-lime. or non-real-time telemetry data streams and automatically append appropriate channel values and limit checks with command and ground event items. Our new closed-loop monitoring tool allows an analyst or mission controller to browse and archive uplink commands and ground events with their corresponding downlinked telemetry values regardless of the delay in downlink telemetry and without requiring mal-time intervention by the user. 1 'igure 1 shows a sample SOE with integrated telemetry channel information.

BACKGROUND

An SOE document is a time-mdcred list of all the planned ground and spacecraft events, including all commands, sequence loads, ground events, significant mission activities, status and resource allocations. The SOE document is generated by the multimission control team by expansion and integration of sequence and ground files. This SOE generation process has been automated and includes a graphical, ohjc.ct-oriented SOE editor and viewing tool running under X/Motif. The SOE is used by the mission controllers and spacecraft and instrument engineers to coordinate their operations tasks, serving as a predict data set in ground operations and mission control.

APPROACH

The Operations Engineering Lab (OEL) proposed a research task to design and implement a toolkit that allows simple, automated integration of predicted uplink events with actual downlink telemetry in a single SOE document for viewing and archiving. This integrated SOE serves as the basis for a closed-loop monitoring toolkit that can automatically interface with existing real-time or non-real-time sources of information and display only selected values from the telemetry data stream.

A significant research effort was in the design and implementation of the interprocess communication interfaces and inter.active controls for retrieving and passing information from a variety of downlink processing applications to the SOE tool. A flexible approach was chosen to allow phasing, of planned future enhancements, including expansion of the SOE capabilities for automated mission controller logs, telemetry logging, system test procedure execution, and automated command verification.

During the requirements analysis, the JPL Multimission Control Team (MCT) indicated that the closed-looJ> monitoring system should include automated log keeping capabilities for mission controllers in order to include their real-time Jogs in the sequence of c.vents. in the current operations environment, the MCT logs real-time information on specific uplink and downlink events on hand- written forms. The MCT cannot meet an electronic logging requirement without automation tools - manually typing a log report would be impossible during intense periods. Although the SOE tool can currently be used to enter comments and act as a logging tool, the mission controller logging requirements were very broad and not clearly defined enough to implement within an already-developed tool such as the SOE editor. '1'bus, we decided to implement a separate tool for automated logging that would integrate manual log inputs, predicted events input files (such as the SOE), real-time broadcast data, and output from other

downlink telemetry processing and monitoring applications.

OEL LOGGING TOOL.

The OEL Logging Tool (OLOG) provides automated and manual logging of predicted and actual mission events in a graphical easy-to-use format. The user interface and pull-down menus are completely configurable by an individual end-user to meet mission-specific needs. An initialization file can be read on startup that customizes menu options and defaults. The OEL Logging '1'001 is shown in Figure 2.

The OEL Log Tool provides capabilities for manual entries to the log, either by allowing a user to select items off prc-defined menus or entering text manually into the entry area. The pm-defined menus and default values can be customized for various teams by creating an initialization file. The OEL Log Tool is also designed to interface in mal-time with external input sources (downlink telemetry, monitor data, interprocess messages, predicts and actuals files), thus providing capabilities for automated log entries. The tool is designed to allow automated and manual log entries to occur concurrently with automatic ordering based on time tags. The current tool implementation includes several mechanisms for communicating with downlink processes basal the MGDS custom Data Transport Subsystem (1)'1'S) services. We have also implemented a telemetry data processing program that captures and processes data from the]cal-time telemetry data stream or spooler files, and passes log messages into the OEL Log '1'001.

INTERPROCESS COMMUNICATION

The OEL Log Tool uses the MGDS 1)'1'S services to implement message passing capabilities. The tool connects to a broadcast channel or virtual circuit if a channel option is chosen. While processing input events, the tool continually checks for pending messages.

Several programs and routines have been written to implement real-time downlink data processing functions and cooperative message passing mechanisms. These programs provide a flexible approach to process various input data sources, which are then reformatted as log messages to be sent to the OEL, 1.og '1'001.

- A program that uses a DTS broadcast channel or virtual circuit for sending time-stamped messages. The OEL Log '1'001 cooperates by receiving and processing the messages for input into the log in time order.

- A generic routine that uses the MGDS Data Transport functions (DTS) to connect to a broadcast channel or virtual circuit for sending lime-stamped messages and a corresponding OEL Log Tool routine that creates a broadcast channel or virtual circuit to receive messages.

- A program that reads the output from an existing real-time Smart Alai.IN Tool. It processes the output and then sends log messages to the ()] ;l. Log '] '00].

- A program that reads MGDS downlinked telemetry data from a virtual circuit, real-time broadcast channel, a bytestream file, and/or a spooler file using the DTS functions. It processes the data by parsing telemetry headers and checking for selected data types which are then Cxtl'acted> processed, and passed to the OEL Log Tool. It uses DTS services to send log messages to the OEL Log Tool. This program provides a model for building additional programs for processing data from real-time telemetry streams or from data output by other applications and then generating log messages to be integrated with the predict information in the log tool.

Figure 3 shows the OEL Log Tool and its telemetry processing interfaces.

CI,0s1 ;D-LOOP sol ; TOOL.

The new closed-loop SOE too] is designed to allow integration of uplink predict events with actual downlink telemetry values.

Ground event and spacecraft command items in the SOE have associated telemetry parameters that can be used to verify the execution of each command or ground event or to establish the state of the spacecraft or ground system. These parameters are HOW interleaved with the commands and ground events in the closed-loop SOE, for easy access and viewing by the analyst. The Closed-loop monitoring system can automatically interface with existing real-time. sources of information, to capture and display actual values from the telemetry data stream. The graphical SOE viewing tool allows a user to highlight events of interest with a mouse on the screen and mark them for automatic alarm notification in real-time. This tool also allows a user to run the SOE in demand mode, specifying any time desired, and to search or Step through the document for events of interest.

The following capabilities have. been incorporated into the SOE tool to implement real-time, closed-loop monitoring capabilities:

- *Real-Time Capabilities*: A scroll bar has been added to allow for scrolling during real-time viewing. Real-time viewing can be accessed and controlled from a menu. It is possible to step through each event under user control or to run the SOE in md-lime or in playback mode. The real-time control capabilities are based on an interrupt algorithm.
- *Channel Objects*: A new item format has been defined for the SOE to allow creation of a telemetry channel object. Each channel object is defined by a description field and is associated with the uplink predict item preceding it. "There can be multiple channel objects associated with a single uplink event. The uplink/downlink command/channel integration is based on cross-referenced information within the telemetry and command dictionaries.
- *Channel Options*: A new option but ton has been implemented that allows a user to optionally display channel records in the SOE.
- *Downlink Interface*: Interprocess communication and data transport functions have been implemented to allow

integration of the downlink telemetry stream.

Figure 4 shows the graphical closed-loop SOE tool.

BENEFITS

New missions arc demanding electronic mission controller logs rather than the current han(i-written reports. Without the automated log keeping, capabilities in the new OEL Log '1'001, a controller would spend most of their time manually typing in electronic log reports.

The closed-loop SOE and OEL Log Tool implementations have laid the groundwork for an advanced closed-loop monitoring system that can significantly reduce the need for operations teams to understand the complex set of processing and display tools in the existing JPL Multi mission Ground Data System (MGDS). The current MGDS approach requires understanding multiple subsystems, and their often subtle interfaces, to allow an end-to-end processing of downlink data. There is also no current method to integrate or compare predict with actual values. The closed-loop SOE tool can greatly simplify a user's ability to access and view telemetry data, and provides a means to view this data in the context of the commands and predicted values that arc used to interpret it. In this context, it is expected that significant cost savings can be realized from the productivity improvements that will be realized over the hundreds of current users of the SOE document and related uplink tools.

Some proposed areas of future work include expansion of the closed-loop SOE capabilities for adaptation to system test, dynamic slams based on tolerances from predicted events, automated monitoring of spacecraft and ground system configurations at selected times, mal-time timeline display of the SOE, generation of as-flown SOE schedules, and automated command verification. An advanced closed-loop monitoring system is essential to a more auto mated monitor and control system and to significant productivity improvements for the smaller missions of the future.

ACKNOWLEDGMENTS

T 1 NE	SC	SYS/STN	EVENT	ACE
1993-203T22:10:27	18	43	Cmd Mod On	KJM
1933 -203T22:15:55	94	45	this is a new message	CSA
1993 -2 80T22:01:40	94	63	U/L Handover DSS -> DSS (18.2 kW RCP)	KJH
1993 -28012 2:10:43	94	DACS2	Cmd Mod Off	KJM
1993-280T22:11:01	94	DACS2	AOS	CSA
1993 -260 T22:24:13	94	UMC S- RT	LOS	KJH
1993-280T22:24:29	94	UMCS-RT	TLM Swap DSS -> DSS (SNR)	KJM
1933 -2 80T22:26:13	94	43	AOS	CSA
1993-280T22:43:03	94	45	HS [n SNR = *, AGC = *	c m
1993 -280 T23:05:52	94	45	Cmd Mod On	KJM
1993-281T01 :09:24	94	UMCS-RT	Cmd Mod On	CSA

| 42: 34m Canberra |
| 43: 70m Canberra |
| 45: IF F Canberra |
| 46: 26m Canberra |

Goldstone.. ▷

Systems.. ▷ Canberra.. ▷

Stations.. ▷ Madrid.. ▷

1994-203T15:37:22 | 94 | 45 | | KJM | Enter

Figure 2 - OEL On-Line Logging Tool (OLOG)

Mission Control Team operations Log

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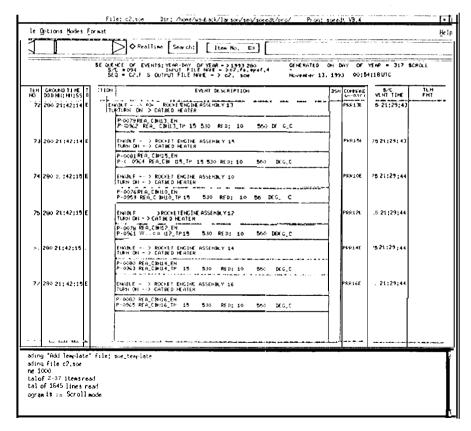| TIME	SYS/STN	EVENT	CE
993- 054T03:00:27	BCUI	001-00:00:00 GLLTISB received SFOC G/W query for routing tbl [054-03:00:27]	IC
993-211T20:46:46	45	s/c 2-Way	ID
993-211 T20:48:38	TLM	Id: **C307** --SCP Telemetry SF DU # 25 IDP-ID ▫ C307 SCP Telemetry 00c0 eb73 0079 1891 0be1 0019 0091 SCLK: 41?158945 Segment: 25 EDF Status Word 0091 MISSION MODE D=0, A=2 EDF Digital Telemetry 68 58 10 7f 7f 40 48 ef ff 9a EDF Analog Telemetry 00 0a 6a 66 7b 01 3c b4 b3 11 46 7a 7b 00 b4 00 7a 78 74 7a 46 88 6e 3b e7 83 bc 83 SCP Status Word de84 from CONTROL SCP CV Word c00G SCP Telemetry c006 c2b0 0001 feec 0001 8c35 13c2 cf54 0eb9 f872 0019 0008 eed8 fffc fb1e ffff 0522 10d8 b061 50e3 0000 0000 ffe8 0067 0032 00000000 5898 49d4 c006 ce30 0001 feec 0001 89f0 1?2d d48e	t'!

Figure 3 - Sample OLOG Printout

Figure 1 - Sequence of Events (SOE) Printout

Figure 4 - Realtime Closed Loop SOE Tool